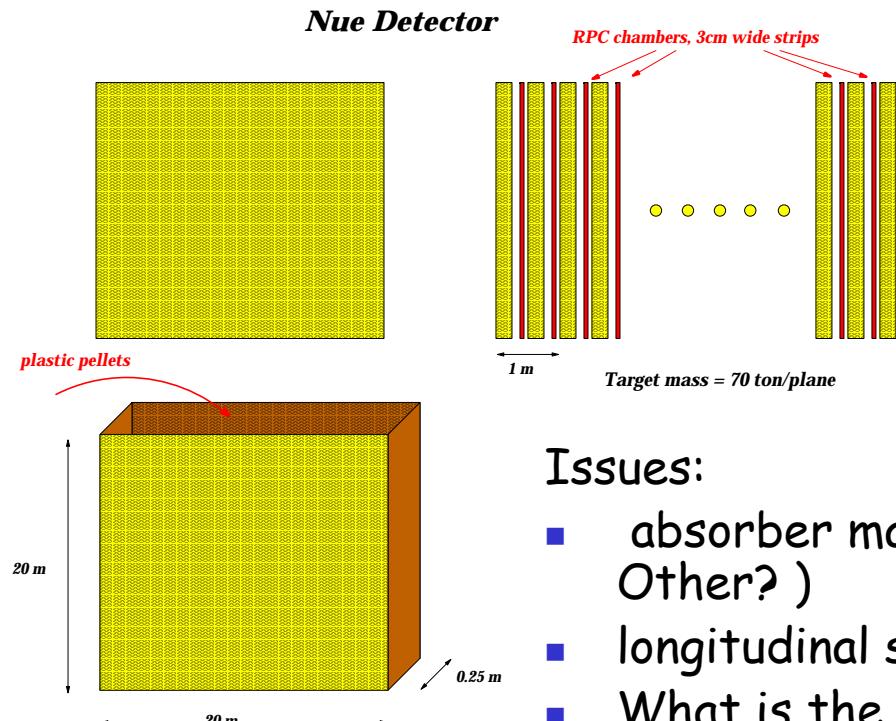


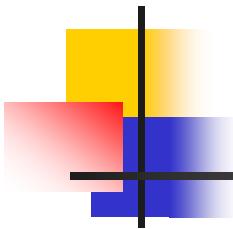
A strawman design of a containerized RPC-based detector

Low Z tracking calorimeter



Issues:

- absorber material (Particle board? OSB?
Other?)
- longitudinal sampling (1/4? 1/3? 1/2? X_0)?
- What is the detector technology (RPC? Drift
tubes?)
- Transverse segmentation 2? 3? 4? 5? cm
- Monolithic? Modular? Containerized? detector
- Distributed electronics? Signal processing at
the outer periphery?



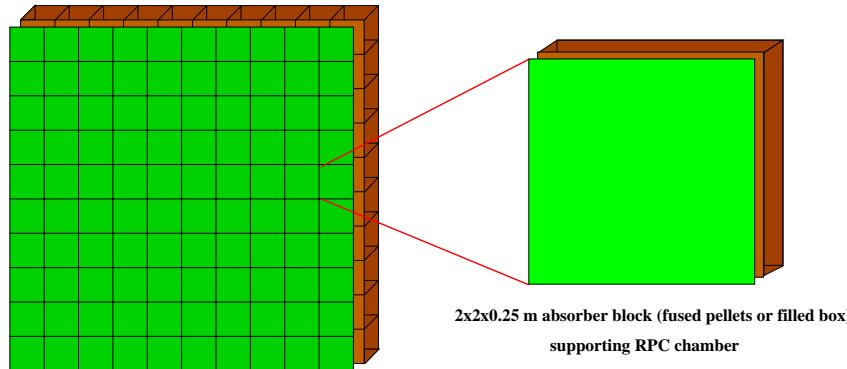
The fundamental issue: low cost detector

- Use standard materials whenever possible:
 - Float glass
 - Particle board
 - Insulation boards
 - Shipping containers
- Use industry standard dimensions (like 20', 4'x8') to minimize customized production
- Modular design to minimize installation/integration effort
- Robust technology to minimize environmental requirements (temperature, pressure, humidity)
- Detector-building interplay: use detector as a structural support for the building?

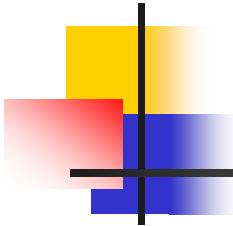
Constructing the detector 'wall'

- Containment issue: need very large detector. Recall: K2K near detector - 1 kton mass, 25 tons fiducial, JHF proposal - 1 kton mass, 100 tons fiducial ← need to understand in details
- Engineering/assembly/practical issues (just think about 7 stories tall thin wall of absorber!)**

Absorber + detector wall stacked in a LEGO-like fashion from fundamental blocks



Solution: Containers ?



Absorber

- Particle board (or equivalent)
 - Cheap
 - Good mechanical properties. Can be used to build a self-supporting detector wall
 - How long is the radiation length?? Assume 45 grams(like plastic), need to verify/measure.
 - 1/3 radiation length sampling \leftrightarrow 15 grams ~ 20 cm ~ 8"

Particle board

MicroFine®

Category	GAYLORD, MI			
	MicroFine® Novoply®		MicroFine® Novoply® Lite	
	in./lbs.	metric	in./lbs.	metric
Density ±5%	45 lbs./ft. ³	721 kg/m ³	43 lbs./ft. ³	689 kg/m ³
Modulus of Rupture	2500 psi	17.24 N/mm ²	2200 psi	15.17 N/mm ²
Modulus of Elasticity	480,000 psi	3310 N/mm ²	440,000 psi	3034 N/mm ²
Internal Bond	80 psi	0.55 N/mm ²	80 psi	0.55 N/mm ²
Screw-Holding: Face	290 lbs.	1290 N	280 lbs.	1245 N
Edge	250 lbs.	1112 N	200 lbs.	890 N
Hardness	900 lbs.	4003 N	850 lbs.	3781 N

MicroFine® Novoply®

Dimensions:

Thicknesses: $\frac{1}{2}$ " (12.70mm) $\frac{3}{4}$ " (19.04mm)
 $\frac{5}{8}$ " (15.87mm) 1" (25.40mm)
 $\frac{11}{16}$ " (17.46mm) $1\frac{1}{8}$ " (28.57mm)

Sizes: 49" x 73" (1244mm x 1854mm)
49" x 85" (1244mm x 2159mm)
49" x 97" (1244mm x 2464mm)
49" x 109" (1244mm x 2768mm)
49" x 121" (1244mm x 3073mm)
49" x 145" (1244mm x 3683mm)
61" x 97" (1549mm x 2464mm)

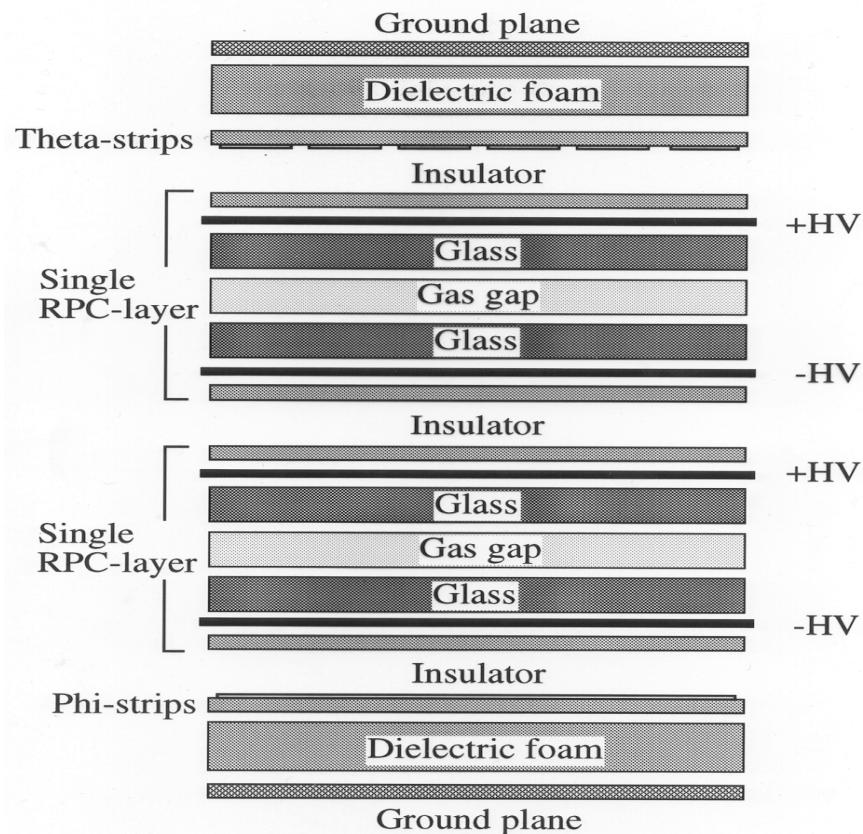
MicroFine® Novoply® produced at Gaylord, MI, is an engineered fines-surface particleboard with a true three-ply construction. Face and core materials are processed under two separate automated systems prior to pressing under heat and pressure. This process reduces high internal stress, one of the major causes of warpage. Resin content and density of the fines-surface layer is higher than the inner core. This contributes to the unique flatness and stiffness of this product. The three-ply construction for MicroFine Novoply functions as an I-beam; that is, the dense high resin content outer plies act as the flange

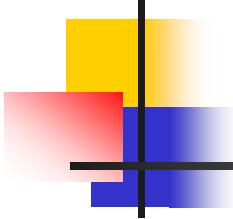
Resistive Plate Counters (Virginia Tech, BELLE)

Glass electrodes are used to apply an electric field of ~4kV/mm across a gap.
(1mm? 2mm?)

The gap has a mixture of argon, isobutane and HFC123a gas. An ionizing particle initiates a discharge which capacitively induces a signal on external pickup strips.

5 years of tests in Virginia Tech, 4 years operating experience in Belle





Why glass RPC's?

- Proven technology (BELLE). Glass avoids all the problems associated with bakelite/linseed oil at the price of poor rate capabilities => well matched to the experimental requirements
- Two spatial coordinates from the same detector plane => maximize the topological information
- Large signals with digital readout => easy and inexpensive electronics
- Easy to form long readout pads by connecting chambers => minimize electronics
- Wide range of acceptable temperatures and pressures => minimize requirements for the building (RPC chambers proven to function down to -12°C, although glass resistivity changes by a factor of 40! Peter Mazur)

Inductive strips readout board - Al Abashian

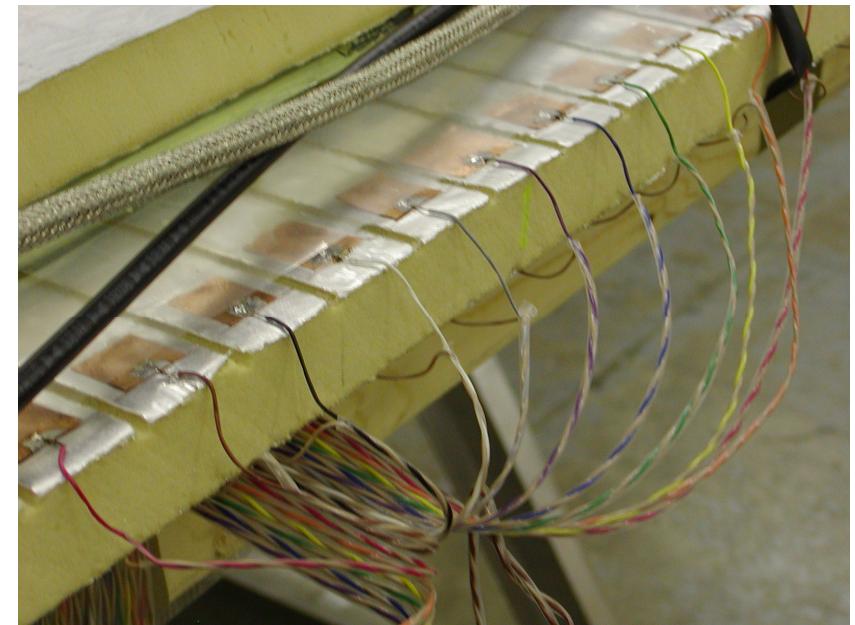


Twisted pair cable +
mass connector

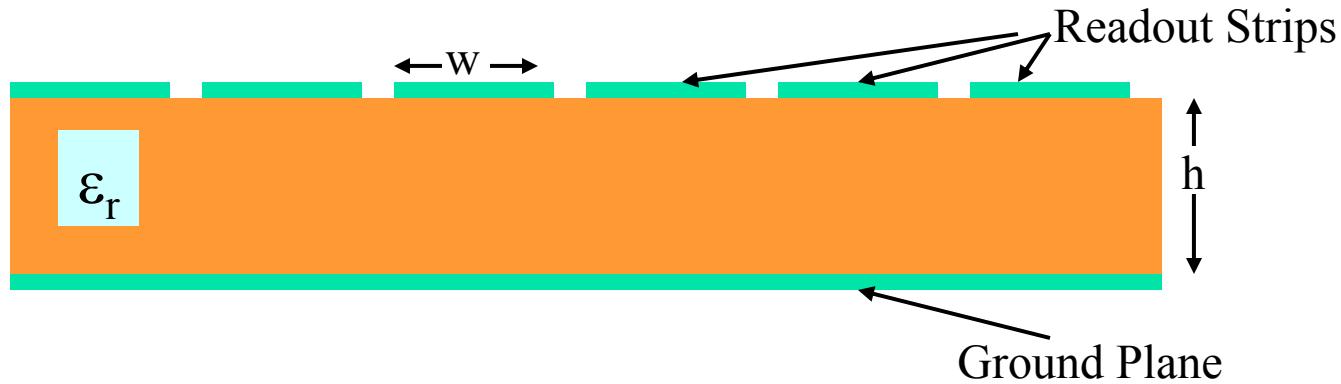
Copper pads glued to
the board to facilitate
cable attachment

Strip readout : transmission
line using insulation board.

Strips cut with a table saw



Transmission Line Impedance



$$Z = \frac{60 \times \ln(8/x + x/4)}{\sqrt{\epsilon_r}} : x < 1$$

$$x \equiv w/h$$

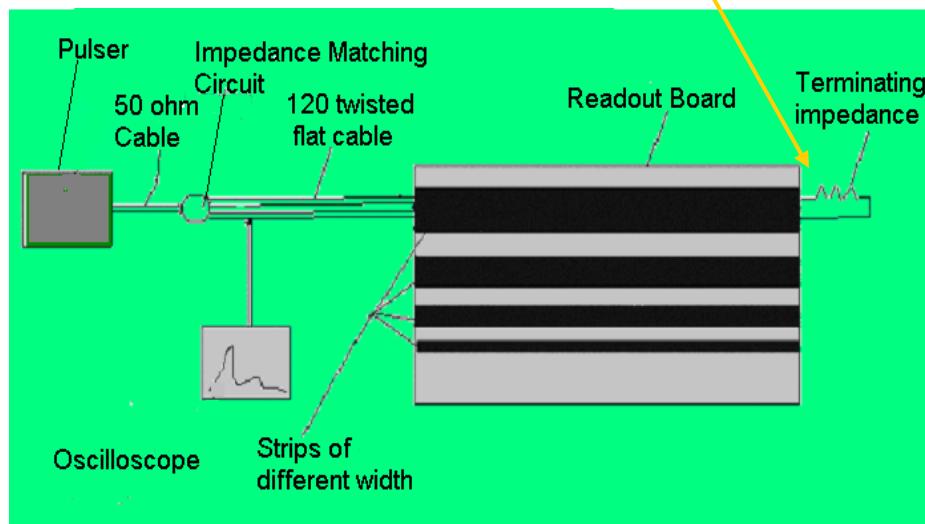
$$Z = \frac{377}{\sqrt{\epsilon_r} (x + 1.393 + 0.667 \ln(x + 1.444))} : x \geq 1$$

$$\epsilon_r' = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} (1 + 10x)^{-\frac{1}{2}}$$

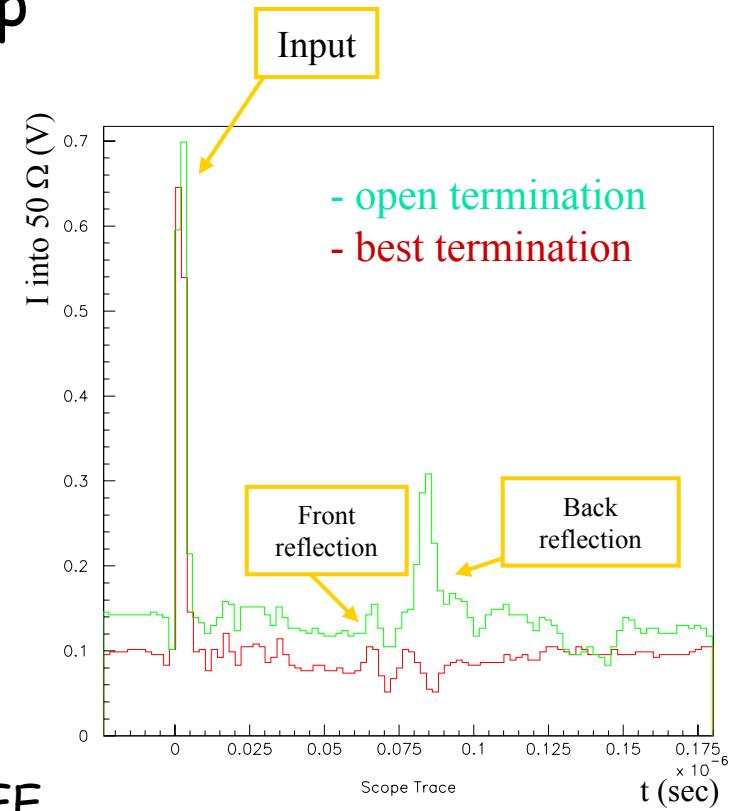
Via G. Drake, from: "Introduction to Electromagnetic Compatibility", Clayton R. Paul, 1992.

Impedance Measurement

- Tune termination for each strip width to get 0 reflected signal for injected charge pulse



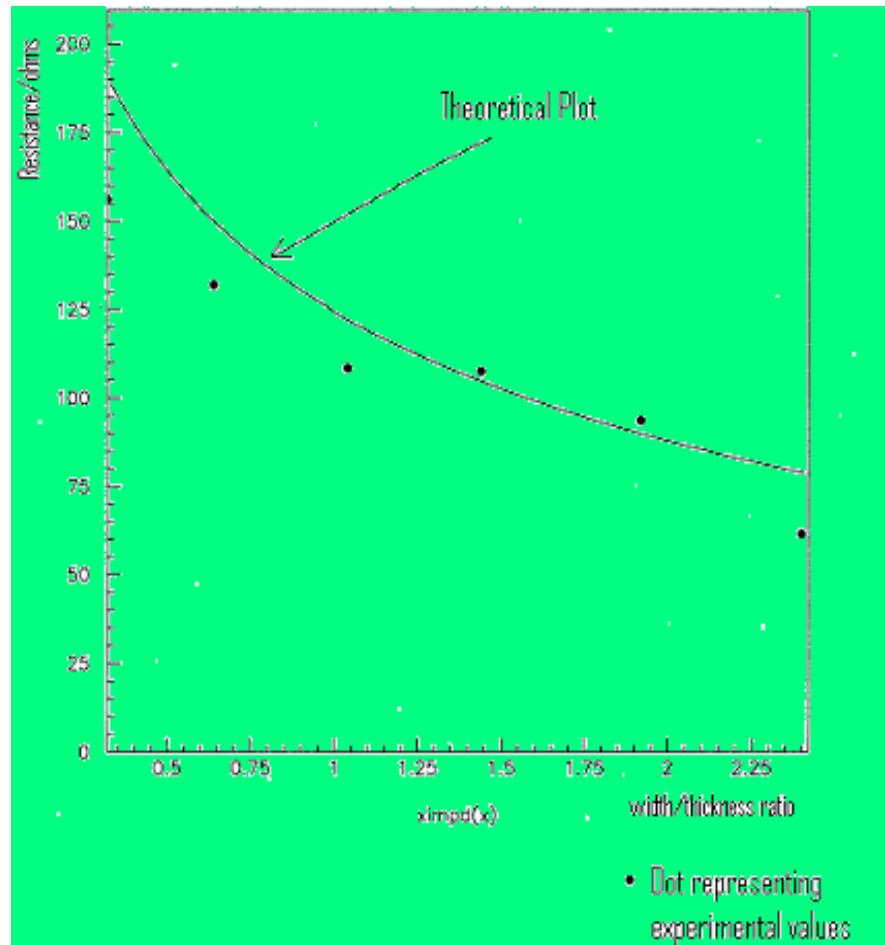
- Summer student Oluwaseun Amoda (EE undergrad from U. Memphis.)

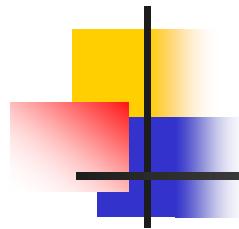


Peter Shanahan, Valery
Makeev, Olu Oamoda, Raoul
Hennings

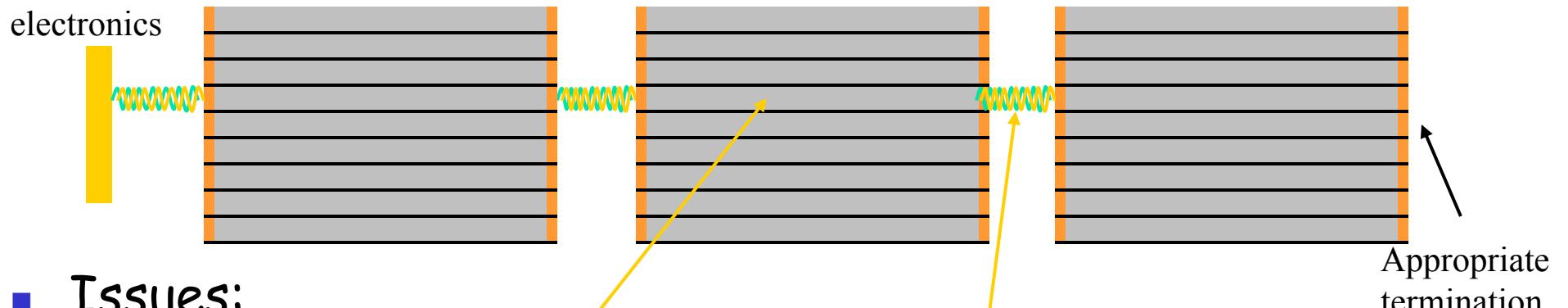
Impedance vs. Width

- General agreement with expected dependence of Z vs. $x=w/h$
- $Z=62 \Omega$ for 3cm strip
 - For $\frac{1}{2}$ " thick board



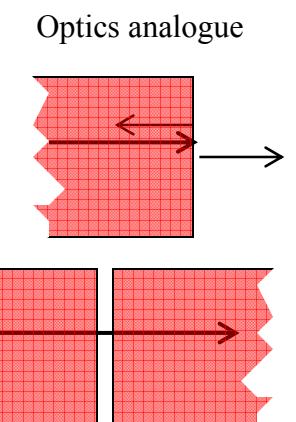


Chained Readout Boards



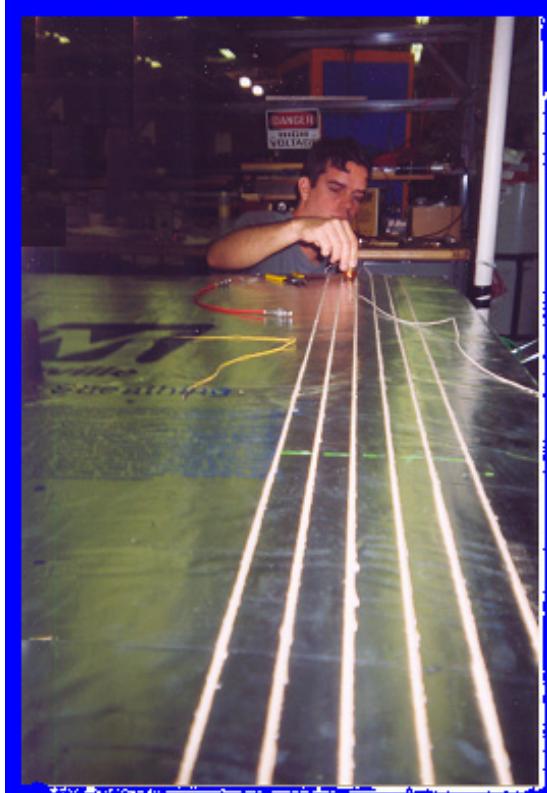
- **Issues:**

- Attenuation in board
- Impedance mismatch (and reflections) at internal boundaries
 - Don't expect it to be important for frequencies below $c_{\text{cable}}/\sqrt{\text{gap}}$ (more simply, won't hurt if propagation across gap is faster than rise time ?)
 - If so, allows up to O(0.5m) or so for interconnections.

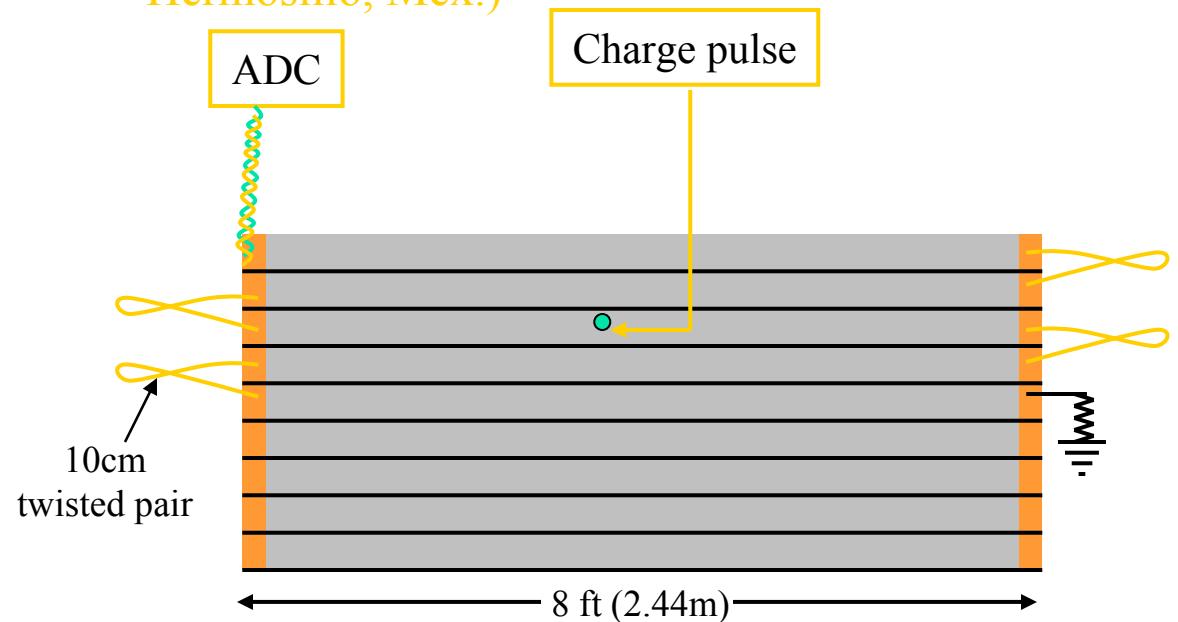


Transmission Measurements

- Measure charge collected from injected pulse as function of distance from readout end

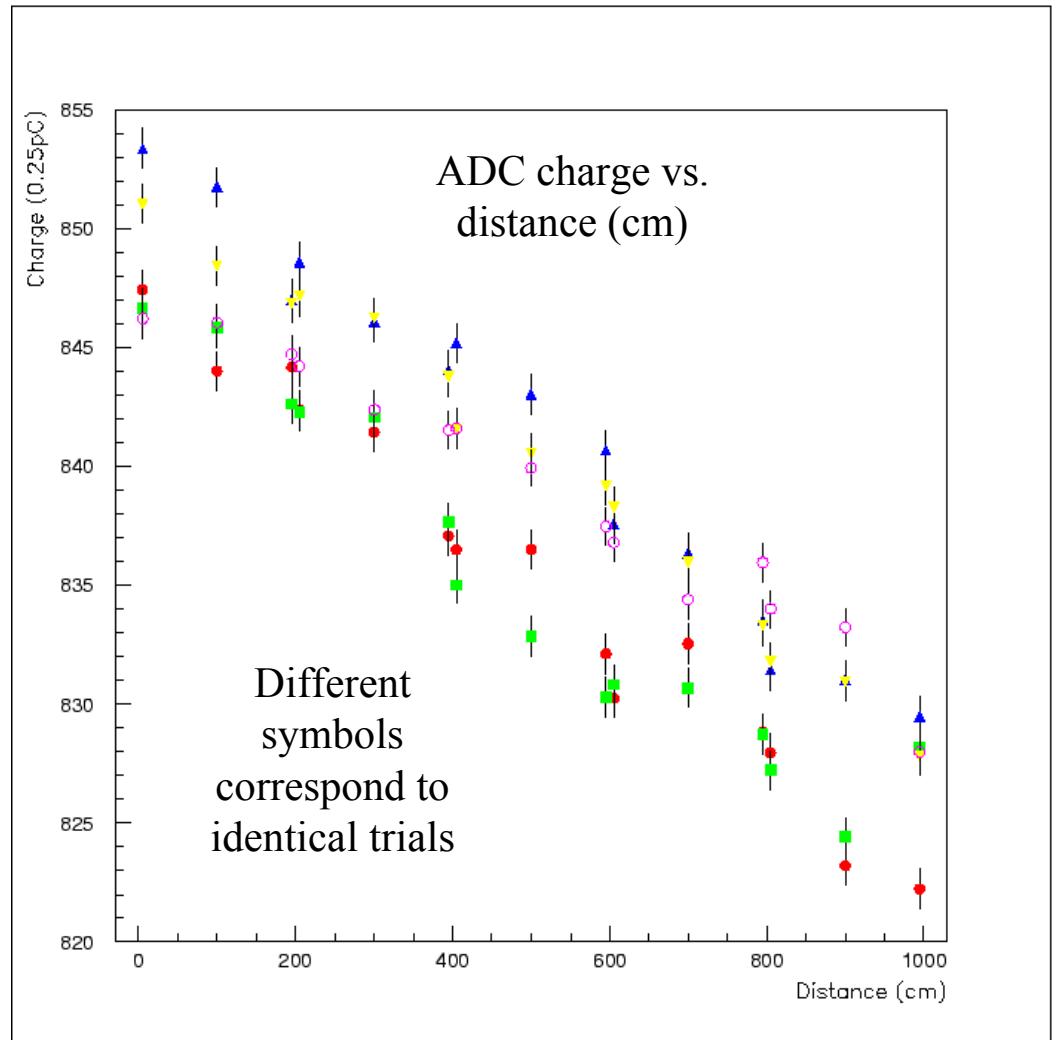


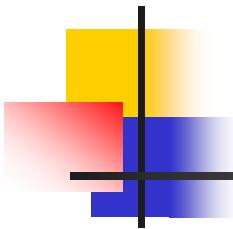
Summer Student, Raul Hennings-Yeomans (Physics undergrad from U. Hermosillo, Mex.)



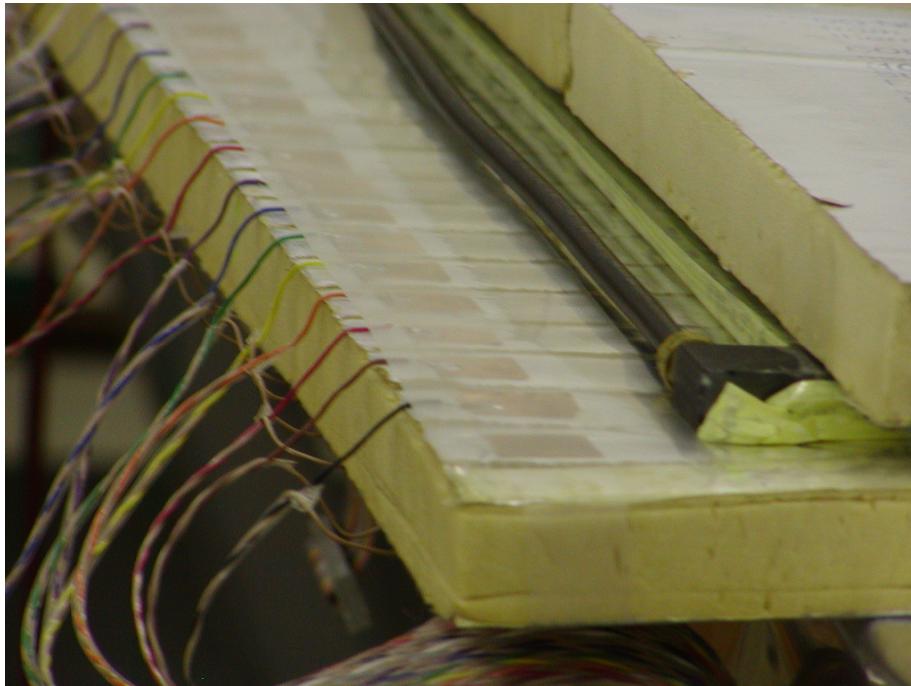
Transmission

- Less than 3% loss over 10 meters
 - This is charge - didn't keep track of peak voltage
- No specific effects due to strip interconnects are visible on scale of 1% uncertainties.

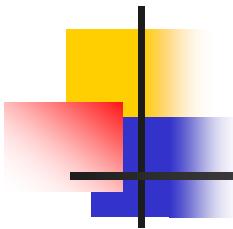




Glass chamber + strips sandwich



Large area glass RPC
sandwiched between two
readout boards: X and Y
coordinate from a single
chamber

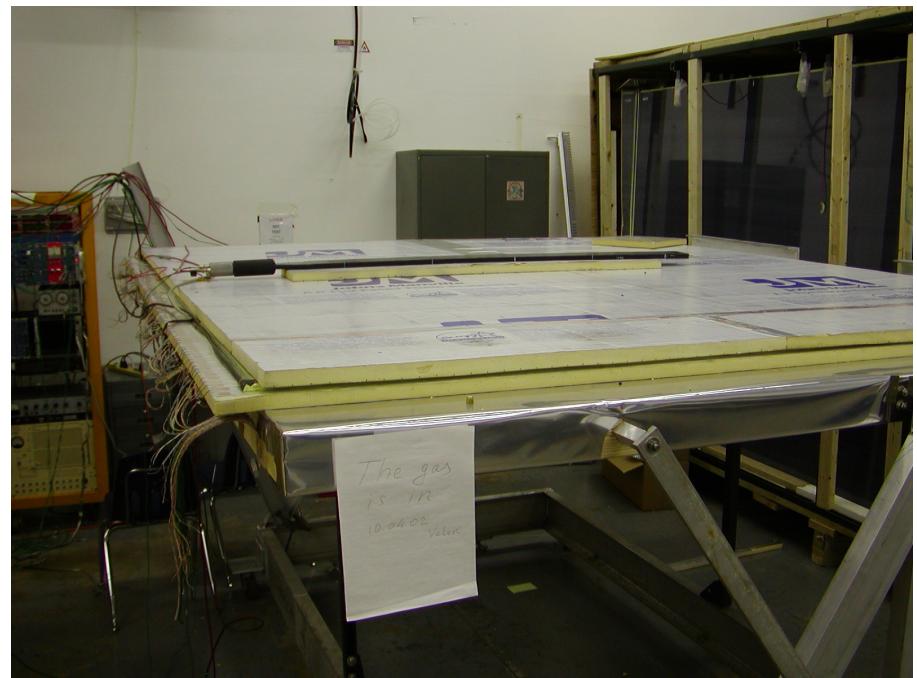


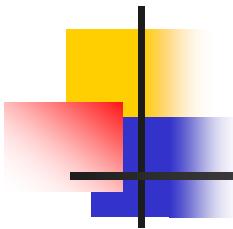
Storing and handling large glass chambers



Rotating table
for handling the
chambers

29 large area GLASS
RPC chambers from
Virginia Tech



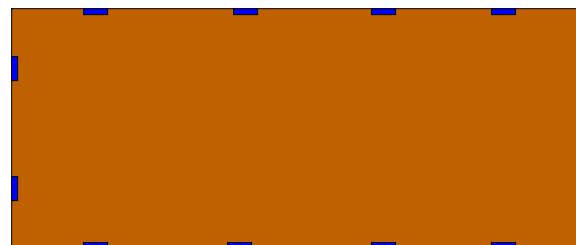


Absorber+RPC module

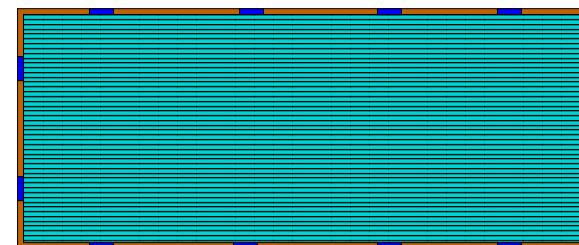
Need to cover
2.4x6 m with
glass
chambers:

- 3 chambers
2x2.4 m?
- 2 chambers
3x2.4 m?
- 5 chambers
0.48x6 m?

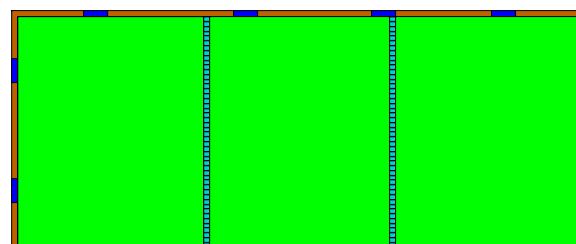
Step 1.: 2.40 x 6.00 m particle board, mount spacers



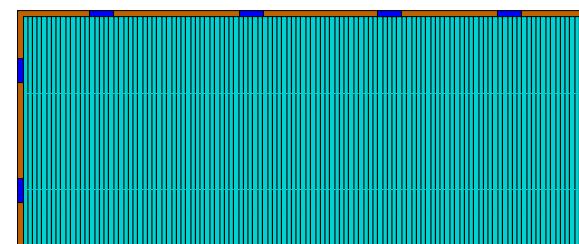
Step 2.: Position x-strips readout board



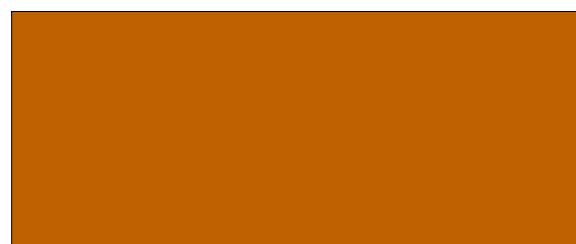
Step 3.: Position 3 glass RPC chambers, 2.00 x 2.40 m each



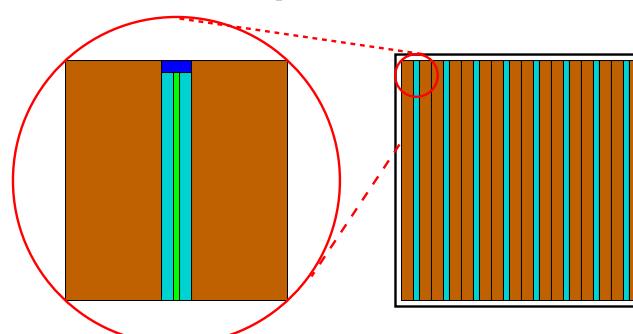
Step 4. Position y-strips readout board

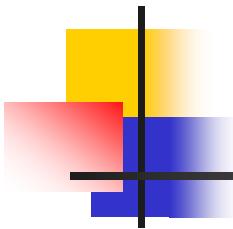


Step 5.: Place the particle board cover

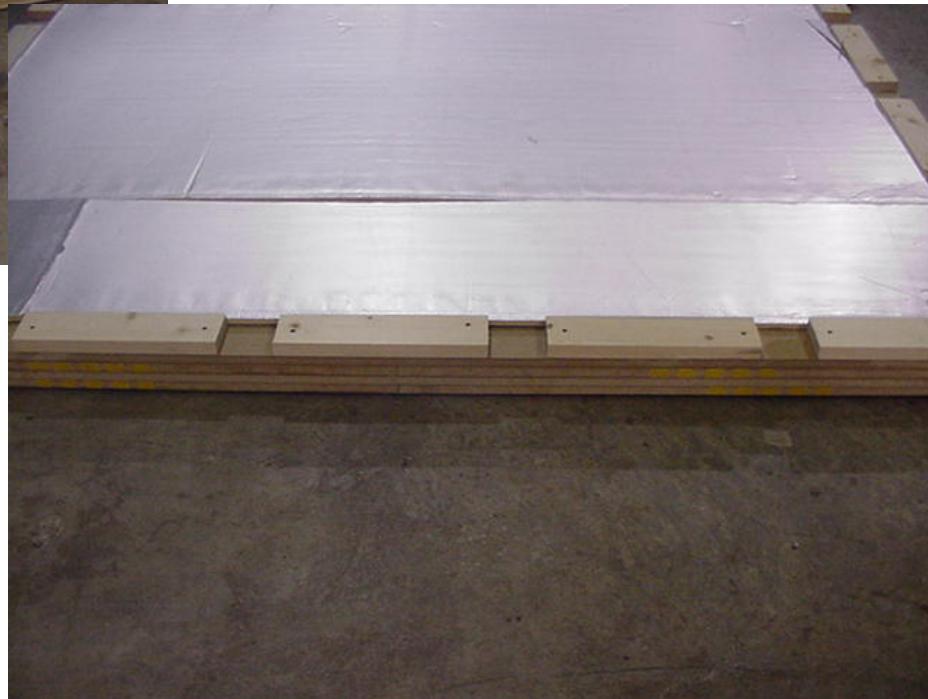


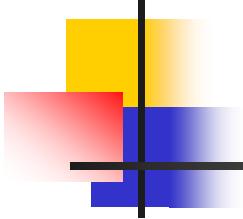
Step 6.: Insert modules into a container





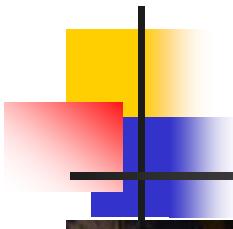
Mechanical prototype of the absorber+chamber module





Fundamental module

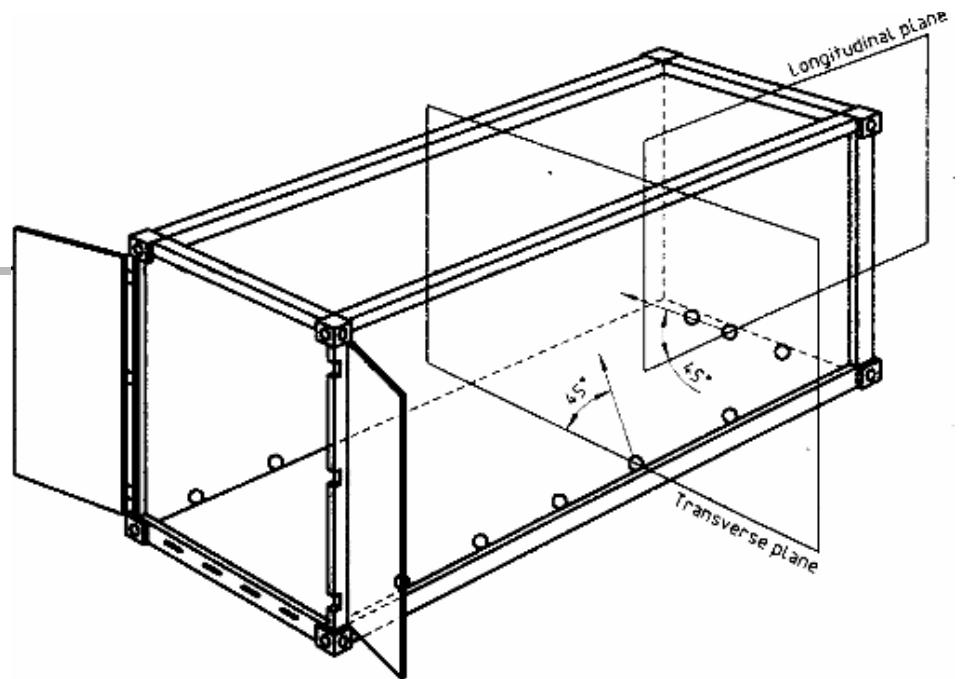
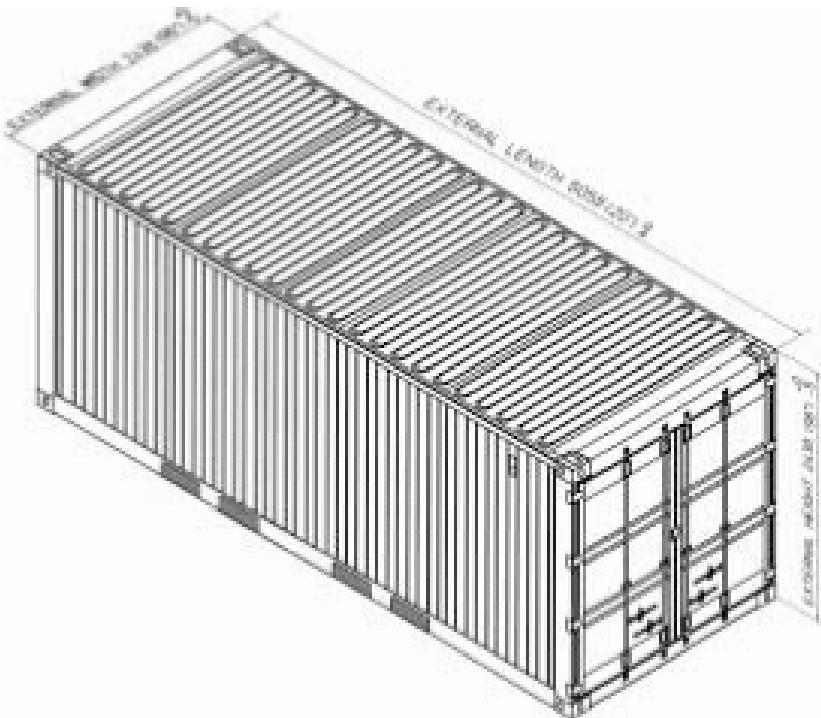
- 8' wide x 20' long x 9.5" thick (8" particle board + 2x0.5" insulation board + 1/3" RPC chamber)
- ~ 2 tons
- Robust unit, easy to handle. Sensitive items protected against possible mishaps.
- 3 chambers ($2 \times 2.4 \text{ m}^2$)
- Gas and HV daisy-chained? Separate lines?
- 80 x readout strips + 200 y readout strips
- 3 flat cables in x, 7 flat cables in y



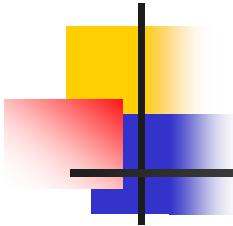
Mechanical prototype of the module



Shipping unit: a container

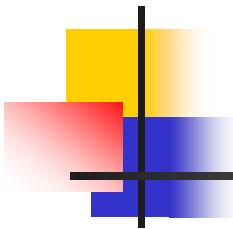


- ISO specifications
- Corner posts take load
- Corner blocks for rigging
- Corrugated steel sides & top
- Doors on one end (or more)
- Hardwood plywood floor sealed to sides
- Angle/channel steel support below floor, fork pockets



Container == a complete piece of a detector

- 10 modules
- 20 tons
- 2000 y strips + 800 x strips
- 10 (30?) HV connectors (on both sides)
- 10 (30?) gas connectors (on both sides)
- 30 flat cables in x, 70 flat cables in y



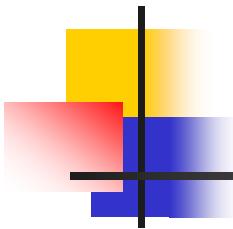
Assembling containers into a detector wall

- Version 1: readout at the periphery
 - Connect x and y strips
 - Daisy chain gas ?
 - Daisy chain HV?

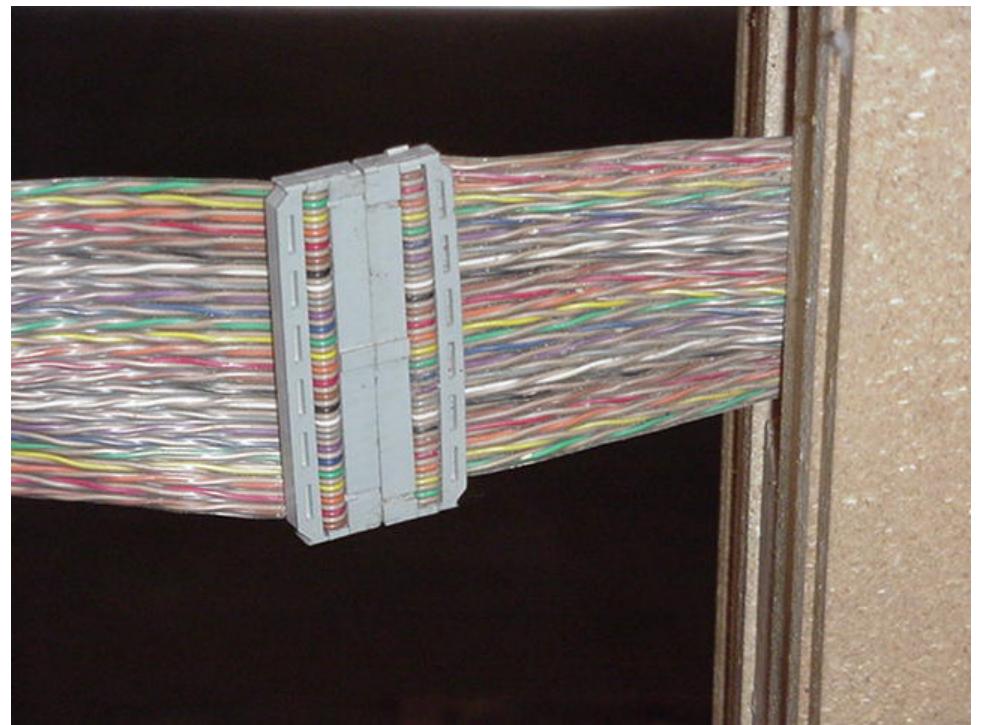
Issue(?):

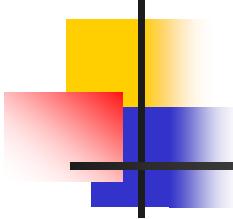
 - 'buried' cable and connectors
 - Container walls are in the way: cut them out? Cut holes?
- Version 2: distributed electronics
 - Front-end readout mounted directly on the readout boards. No cables or connectors

Issue: cost of electronics



Signal cables at the edge of a module





Connecting strips across containers

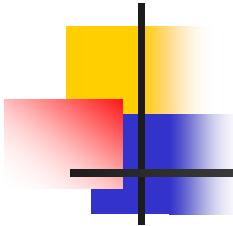


Position one container

Connecting containers
requires 3 openings in
side walls and 7 openings
in top/bottom

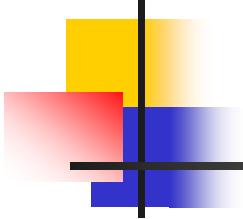


- Bring neighboring container
- Connect the strips
- Close the gap



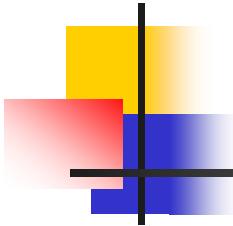
A container wall

- Stack 8 containers high and 4 containers wide wall → $32 \text{ containers} \times 20 \text{ ton} = 640 \text{ tons}$
- For 20 ktons one needs 31 container walls, or 992 containers
- Assuming 20 cm distance between walls it gives a detector which is 80 m long



Production/construction scenarios

- Some labs construct 'components':
 - Coated and tested glass
 - Electronics
 - Gas distribution
 - HV distribution
- Some labs construct detector modules, insert into containers. Check out/calibrate the container-detector
- Containers are shipped to the detector site and integrated into the detector volume.



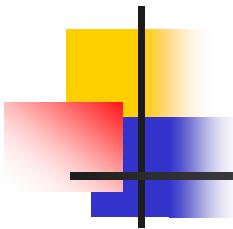
Monolithic detector variant:

- Variant 1:

Fundamental building blocks are constructed by gluing 1" boards displaced by 2(?)" in x and y. Modules are shipped in the containers. At the detector site the modules are assembled into a large plane in a lego-like fashion. Planes are cross-connected to provide stability. Uniform detector with no voids/dead spaces.

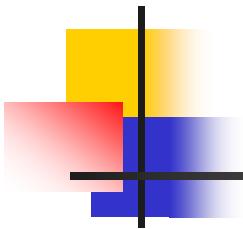
- Variant 2:

Modules are shipped in the containers, as always. Large rack is constructed to hold the modules and to provide the support for the building.

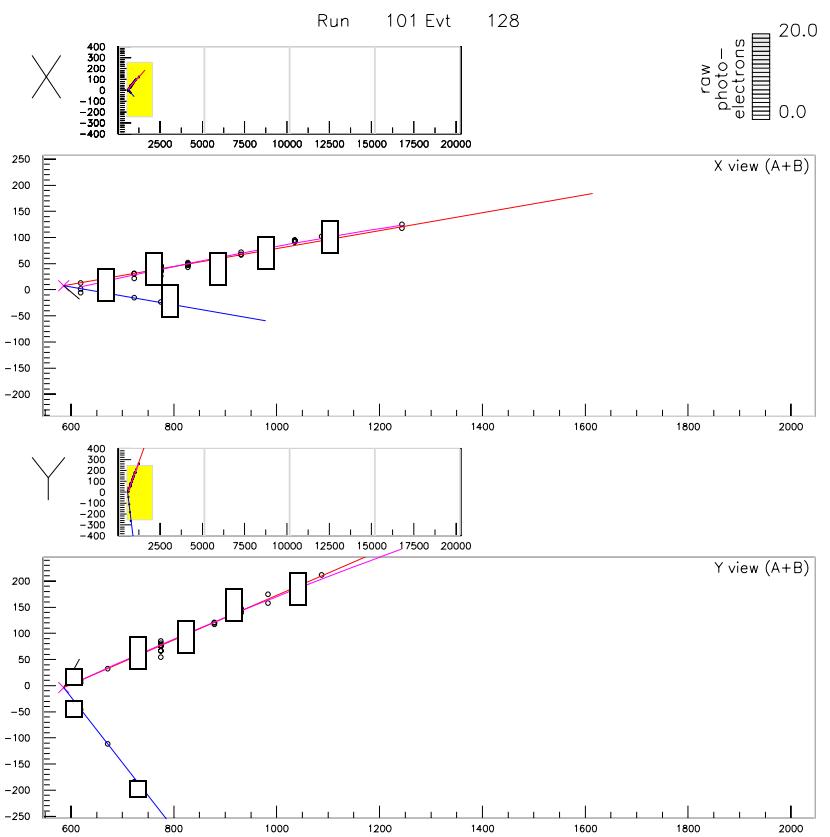
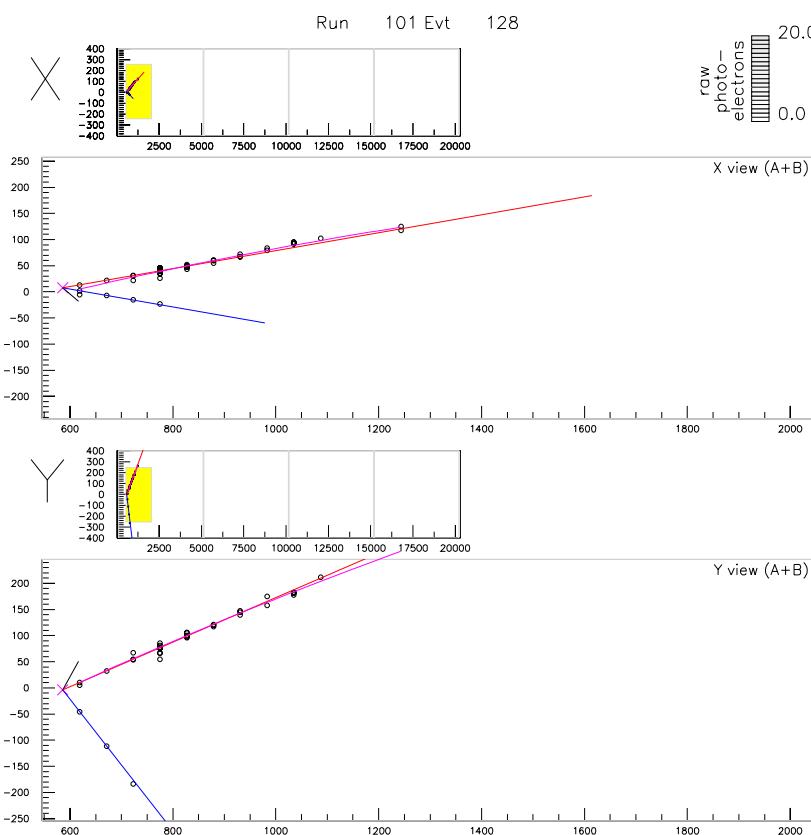


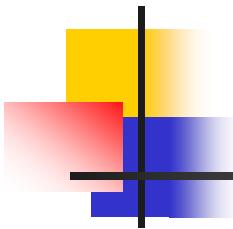
Detector cost?

- Cost estimates make little sense without a complete design of a detector including fabrication, testing and integration
- Cost estimate of a '20 kton' detector requires optimization of the longitudinal segmentation and (to a lesser degree transverse segmentation of the detector)
- What counts is fiducial mass, not a total mass. More detailed studies needed to understand the containment requirement
- A proposal: for the purpose of comparison assume:
 - 1/3 X₀ longitudinal segmentation (in each view, or demonstrate equivalence in electron ID efficiency)
 - 3 cm strips
 - 2 m cut around the edges (or 20x20 m detector)



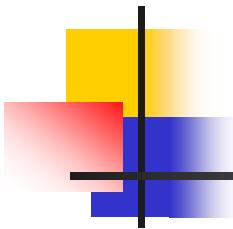
How many dimensions?





Containerized RPC detector, salient features

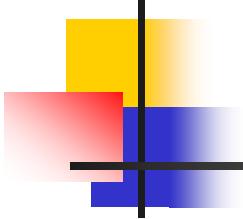
- Uniform response over the entire volume (no factor 15 difference left-to-right, top-to-bottom)
- Fast response. Event integration time ~50 nsec. Factor of 200 better rejection against backgrounds than II/CCD
- Simple, reliable, easy to build detectors
- Relatively small modules to build and handle
- Utilize industrial solution for construction of a huge detector volume
- Minimize testing/calibration/integration by shifting these efforts to production centers (excellent opportunity to educate and train students!)
- Relatively simple and inexpensive transport
- Inexpensive electronics
- Wide range of environmental conditions acceptable



Cost elements

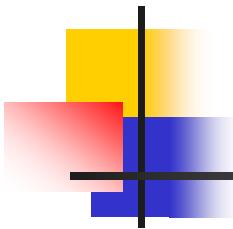
Needs
thought
and
ideas

→	■ 120,000 m ² (== 400 m ² × 300 planes) of chambers @ \$150/ m ²	\$18 M
	■ 1000 shipping containers	\$2.5 M
	■ Particle boards	\$4.5 M
	■ 500,000 electronics channels (300 X [700+700]) @ \$10/ch	\$ 5M
	■ Gas system	\$ 2M
	■ HV system	\$ 3M
	Total (so far)	\$35 M



Conclusion

- Glass RPC + particle board + shipping containers offer a practical solution to a problem of constructing a huge volume detector
- Detector is modular with fundamental building blocks relatively simple to construct
- Industrial solutions used the challenging problem of scale
- Detector well suited for construction at a distributed centers
- Whereas the construction techniques exist, major cost savings can be, perhaps, realized with an additional effort towards industrialization of the glass chambers
- If not, what are the most obvious weaknesses?



Questions

- is all this detector concept solid enough to claim 'readiness' for construction?
- If not, what are the most obvious weaknesses?